Computational Logic

Functional Programming
WS 2007/08

Christian Sternagel[1] (VO + PS)
Friedrich Neurauter[2] (PS)
Harald Zankl[3] (PS)

Computational Logic
Institute of Computer Science
University of Innsbruck

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[1] christian.sternagel@uibk.ac.at
[2] friedrich.neurauter@uibk.ac.at
[3] harald.zankl@uibk.ac.at

Overview

Week 9 - Combinator Parsing
- Summary of Week 8
- Motivation
- Combinator Parsing
- An Example Parser

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Efficiency of Functional Programs

Avoid unnecessary recomputations by ...

- tupling

Introduce tail recursion by ...

- parameter accumulation

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What is Parsing?

Parsing is the decomposition of a linear sequence into a structure, given by a grammar. The linear sequence may be a text in some natural language, a computer program, a web site, a piece of music, a sequence of genes, . . .

In the Following . . .

Use

- linear sequence: l-string (i.e., char list)
- structure: some user-defined type
- grammar: BNF (Backus-Naur form)

Note

- BNF can express context-free grammars (CFG)
- combinator parsers can parse context-sensitive grammars
- however, for the purpose of this lecture CFG suffice

Example: Arithmetic Expressions

Grammar

$$e ::= e + t \mid t$$
$$t ::= t * f \mid f$$
$$f ::= (\ e\ ) \mid n$$
$$n ::= \epsilon \mid d\ n$$
$$d ::= 0 \mid \dots \mid 9$$

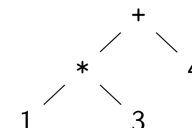
e	. . .	"expression"
t	. . .	"term"
f	. . .	"factor"
n	. . .	"natural number"
d	. . .	"digit"

Structure - Abstract Syntax Tree (AST)

```
type arith =
  | Num of Strng.t
  | Add of arith * arith
  | Mul of arith * arith
;;
```

Example

- input: "1*3+4"
- AST:



Parsers

First Attempt

- functions of type Strng.t −> ('a ∗ Strng.t)
- e.g., digit ['1'; '2'] results in ('a', ['2'])
- but there is information missing, e.g.: *error?* or *input consumed?*

Type of parsers

```
type 'a result;;
type 'a t = Strng.t −> 'a result;;
```

- result is an abstract data type (ADT)
- the only thing known about parsers is that they take an l-string as input and return *some* result

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The Internal Representation

Type

```
type 'a reply = Error | Ok of ('a ∗ Strng.t);;
type 'a consumed = Empty of 'a | Consumed of 'a;;
type 'a result = ('a reply) consumed;;
type 'a t = Strng.t −> 'a result;;
```

- reply keeps record whether error occurred or not
- consumed keeps record whether input has been consumed
- result combines both pieces of information
- concrete type only visible within Parser module

A Framework for Using Parsers

Checking for errors

```
let reply = function
  | Empty r −> r
  | Consumed r −> r
;;
```

```
type 'a reply = Error | Ok of ('a ∗ Strng.t);;
type 'a consumed = Empty of 'a | Consumed of 'a;;
type 'a result = ('a reply) consumed;;
type 'a t = Strng.t −> 'a result;;
```

Applying a Parser

```
let parse p s = match reply (p s) with
  | Error −> failwith "Parser.parse: no successful parse possible"
  | Ok (x, _) −> x
;;
```

For Convenience

```
let test p s = parse p (Strng.of_string s);;
```

Primitive Parsers

Sat

```
let sat p = function
  | [] -> Empty Error
  | c :: cs -> if p c then Consumed (Ok (c, cs)) else Empty Error
;;
```

- only primitive parser
- sat p accepts any character for which p is **true**

Example

```
# sat ((<>) 't') ['a'; 't'];;
- : (char reply) consumed = Consumed (Ok ('a', ['t']))
```


Primitive Parsers (cont'd)

Any char

```
let any_char = sat (fun _ -> true);;
```

- accepts any single character

Character

```
let char c = sat ((=) c);;
```

- accepts only the given character c

Parser Combinators

Bind

```
let (>>=) p f = (fun s -> match p s with
 | Consumed r -> begin match r with
  | Ok (x, s') -> begin match f x s' with
   | Empty r' -> Consumed r'
   | consumed -> consumed
  end
  | Error -> Consumed Error
 end
 | Empty r -> begin match r with
  | Ok (x, s') -> f x s'
  | Error -> Empty Error
 end
);;
```


Parser Combinators (cont'd)

Then

```
let (>>) p q = p >>= fun _ -> q;;
```

Example

- *p* ::= a b
- `let p = char 'a' >>= fun _ -> char 'b';;`
- `let p = char 'a' >> char 'b';;`
- i.e., (>>=) and (>>) correspond to juxtaposition in BNF
- (>>=) is used if result matters
- (>>) is used otherwise

Parser Combinators (cont'd)

Choice

```
let (<|>) p q = (fun s -> match p s with
  | Empty Error -> q s
  | other -> other
);;
```

Example

- p ::= a | b
- **let** p = char 'a' <|> char 'b';;
- i.e., (<|>) corresponds to | in BNF

Parser Combinators (cont'd)

Return

```
let return x = fun s -> Empty (Ok (x, s));;
```

Example

```
let any_pair =
 any_char >>= fun l ->
 any_char >>= fun r ->
 return (l, r)
;;
```


Parser Combinators (cont'd)

Many

- many p applies p *zero* or more times
- result is list of results of p
- greedy (as many applications of p as possible)

Example

- $p ::= \epsilon \mid$ a p
- **let** p = many (char 'a')

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Recall

Grammar

$$e ::= e + t \mid t$$
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$$n ::= \epsilon \mid d\ n$$
$$d ::= 0 \mid \ldots \mid 9$$

Structure (Abstract Syntax Tree)

```
type arith =
 | Num of Strng.t
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 | Mul of arith * arith
;;
```


Week 9 - Combinator Parsing An Example Parser

The First Attempt

```
let rec e x = (
  (e >>= fun e1 -> char '+' >> t >>= fun e2 -> return (Add (e1, e2)))
  <|> t
) x
and t x = (
  (t >>= fun t1 -> char '*' >> f >>= fun t2 -> return (Mul (t1, t2)))
  <|> f
) x
and f x = (
  (char '(' >> e >>= fun e -> char ')' >> return e)
  <|> n
) x
and n = many1 digit >>= fun r -> return (Num r);;
```

Problem

left recursion

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Solution: Eliminate Left Recursion

Revised Grammar

$$e ::= t\ e'$$
$$e' ::= +\ t\ e' \mid \epsilon$$
$$t ::= f\ t'$$
$$t' ::= *\ f\ t' \mid \epsilon$$
$$f ::= (\ e\ ) \mid n$$
$$n ::= \epsilon \mid d\ n$$
$$d ::= 0 \mid \ldots \mid 9$$

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Week 9 - Combinator Parsing An Example Parser

The Final Parser

```
let rec e x = (t >>= e') x
and e' l =
  (char '+' >> t >>= e' >>= fun r -> return (Add (l, r)))
  <|> return l
and t x = (f >>= t') x
and t' l =
  (char '*' >> f >>= t' >>= fun r -> return (Mul (l, r)))
  <|> return l
and f x =
  ((char '(' >> e >>= fun r -> char ')' >> return r) <|> n) x
and n = many1 digit >>= fun r -> return (Num r);;
```

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